Oil Price Dynamics and Returns of Renewable Energy Companies

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Abstract

We investigate the effects of changes in the crude oil price on stock returns of renewable energy companies. Hereby, we examine more than 20 companies from different industries with focus on renewable energy sectors like fuel cells, photovoltaics, biomass etc. that are listed in the NASDAQ. The time period considered includes data from January 2001 to July 2008 and can be split into three subperiods: from January 2001 to December 2003 when the oil price remained relatively constant around a level of 30 USD, the period from January 2004 to February 2007 when the oil prices showed an overall tendency to increase up to 60 USD and the period from March 2007 to July 2008 when an extreme increase in the prices up to 140 USD could be observed. Using an approach based on the capital asset pricing model (CAPM) and a multiple regression factor type model, we analyse the systematic risk for the renewable energy companies relative to the market performance. Our results are ambiguous and do not support the assumption that during times of oil price shocks higher investments and returns can be obtained from renewable energy stocks. On the other hand we find a more significant influence of oil prices on renewable energy stocks when the former are steeply increasing what at least partially confirms results by earlier studies.

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1 Introduction

It is generally agreed upon that concerns about future oil shortages and rising oil prices should increase the interest in investments in alternative energy sources, see e.g. Bleischwitz and Fuhrmann (2006); McDowall and Eames (2006). As a recent UNEP study reports, capital flowing into renewable energy climbed to a record 100 Billion in 2006 United Nations Environment Programme (2007) while also according to various reports in the media, investors are expecting to make a respectable profit as returns on green investments are rising (Financial Times, 2006). Overall, one shouls expect that various factors like global warming, restricted oil supplies, increased global demand, and political insecurity in some of the oil producing countries and will not only lead to rising oil prices but also to a greater demand and supply of alternative energy sources.

As a globally traded commodity, the price of oil is determined by global demand and supply. Therefore, the rapidly increasing demand for oil from emerging market economies like China or India in the long run will lead to much higher oil prices in the future. Further, the political uncertainty in regions of the world oil reserves oil creates a security issue for the large oil consuming countries. Finally, the increased concentration of CO_2 levels in the atmosphere contributing to global warming is quite likely to further increase prices of carbon intensive goods like oil based on introduced carbon taxes or cap and trade systems in various countries. Overall, these factors in the long run are a strong argument for an eventual substitution away from oil to alternative energy sources (Henriques and Sadorsky, 2008).

In this paper, we investigate the effects of changes in the crude oil price on individual stock returns of renewable energy companies. Our analysis involves more than 30 companies from different industries with focus on renewable energy sectors like fuel cells, photovoltaics, biomass etc. that are listed either in the NASDAQ or NYSE. In our study we follow the techniques applied in similar studies investigating the effects of oil price dynamics or shocks on stock market returns. Usually the analysis is conducted by using CAPM type, multiple regression or vector-autoregressive models with various factors like stock market returns, oil and gas prices or interest rates. The literature provides a variety of results on the issue, however only one study sets the focus in particular on returns of an index of alternative energy stock prices. Faff and Brailsford (1999) investigate the relationship between the oil price and stock market indices of various industries. They find significant effects of oil prices on Australian industries, in particular the oil, gas, resource and building industry. Sadorsky (2001) finds significant positive effects of an increasing oil price on Canadian oil and gas stocks while Boyer and Filion (2004) also find a positive relationship between oil and natural gas prices and stock returns on Canadian oil and gas companies. To our knowledge, the only study mainly concerned with the relationship beeen oil prices and the returns of renewable energy companies is Henriques and Sadorsky (2008). Here, a four variable vector-autorfegression (VAR) model is used to investigate the empirical relationship between alternative energy stock prices, technology stock prices, oil prices and interest rates. The authors find that both technology stock prices and oil prices each individually Granger cause the stock prices of alternative energy companies. However, a shock to technology stock prices overall has a larger impact on alternative energy stock prices than does a shock to oil prices.

Our study extends the previous work in the field by investigating individual companies and splitting the observation period into three subperiods: from January 2001 to December 2003 when the oil price remained relatively constant around a level of 30 USD, the period from January 2004 to February 2007 when the oil prices showed an overall tendency to increase up to 60 USD and the period from March 2007 to July 2008 when an extreme increase in the prices up to 140 USD could be observed. Hereby, we concentrate on the question whether an increase in oil prices leads to higher investments in renewable energy sectors, yielding higher or abnormal returns for such companies on the stock market. Further we are interested in the relevance of oil price movements on the returns of individual renewable energy companies: generally one would expect that during the phase of a steady climb of oil prices, the influence of the 'systematic' factor oil on stock returns will be higher than for the phase where oil prices remained rather stable.

Therefore, using an approach based on the capital asset pricing model (CAPM), we analyse the systematic risk for the renewable energy companies relative to the overall market that is measured by a stock's beta-factor. Further investigating the issue, we estimate a multiple regression model that next to market returns also includes the change in the crude oil price and the riskless interest rate as explanatory factors. Examining the explanatory power of the CAPM type model and we find that for periods of rising oil price, the models on average have a very low explanatory power. On the other hand, we also the factor models also including the variables oil price and riskfree treasury rate yield a higher explanatory power. We further examine whether for any of the subperiods significant abnormal returns for the renewable energy companies can be observed.

If the assumption of higher investments in renewable energy companies during times of oil price shocks is correct we would expect significant changes in the estimated coefficients. As we will see in the empirical analysis this is not the case: in fact the number of companies with average positive abnormal returns was even the smallest during the subperiod with a steeply increasing oil price. On the other hand we are interested in the significance of changes in the oil price on the returns: we find that for the estimated factor models, the number and significance of positive coefficients for the variable increases substantially for the subperiods with increasing oil prices. In particular for companies in the fuel cell and photovoltaic industry there seems to be a significant positive influence on changes in the oil price on stock returns.

The remainder of the paper is set up as follows. Section 2 provides an overview of the considered data and models. Section 3 gives empirical results for the estimated models focusing on the explanatory power of the models, abnormal returns and the influence of oil price changes on stock returns. Section 4 concludes.

2 Data and Models

2.1 The Data

In our study we selected monthly returns of 23 renewable energy firms listed on the NASDAQ. These list of the firms were sourced from the website, www.renewableenergystocks.com, which categorizes renewable energy firms into different forms of renewable energy. Note that only companies providing stock prices from January 2001 to July 2008 were included in the analysis. During this time period a number of companies were taken over by other companies and had to be excluded from the analysis. Further several of the companies listed on the website do not provide historical prices going back to 2001. Overall, the considered time period ranges from the 2nd of January 2001 to the 1st of July 2008 yielding 90 observations of monthly returns for each of the considered firms. Table 1 gives an overview of the different industries for the companies including flywheel-based energy storage devices, fuel cells, micro turbines, photovoltaics, biomass, biogas and ethanol as well as more general products or services that allow clients to improve their usage of energy.

Table 2 gives an overview of the considered companies in the analysis. The table provides the company name, abbreviation as well as the industry description for each of the considered companies. Note that the highest number of companies belong to the categories fuel cells or the more general product and services.

Figure 1 provides a plot of the oil price for the considered time period from Janury 2, 2001 - July 1, 2008. The graph also indicates the considered subperiods from January 2001 to December 2003 when the oil price remained relatively constant, the period from January 2004 to February 2007 when the

Industry	Description of this industry
Flywheel	Flywheel-based energy storage devices
Product or service	Product or service that allow clients to improve their usage of energy
Fuel Cells	A fuel cell is an electrochemical energy conversion device
Micro Turbines	Very-low-emission micro turbine systems used for onsite power production
Photovoltaics	Photovoltaics (solar cells) are semiconductor devices that convert sunlight into direct current
General 1	Advanced optoelectronic and signal processing services and products)
General 2	The manufacture, marketing, and development of carbon fibers for various applications
Biomass	Alternative fuel source from organic resources
Biogas/Ethanol	Alternative fuel source from plants

Table 1
Suggested categories of renewable energy stocks according to www.renewableenergystocks.com.

oil prices showed an overall tendency to increase up to 60 USD and the period from March 2007 to July 2008 when a steep increase in oil prices up to 140 USD could be observed.

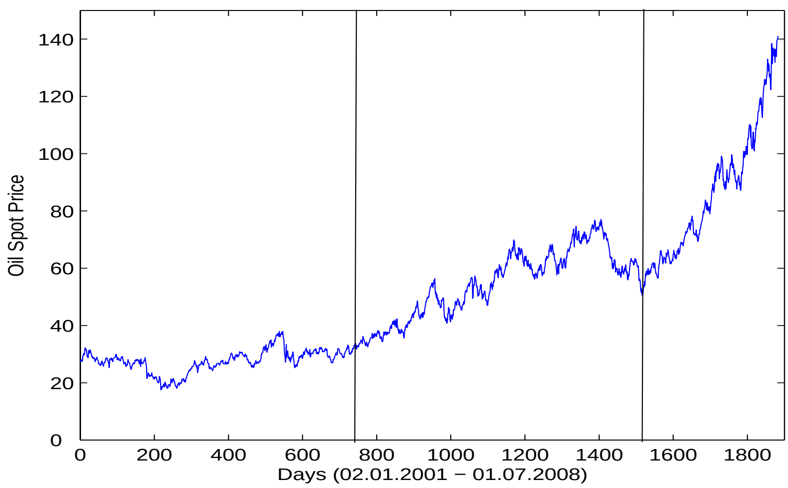

Fig. 1. Oil price for the considered time period from Janury 2, 2001 - July 1, 2008. The graph also indicates the considered subperiods.

Figure 2 provides a plot of the NASDAQ index for the considered time period from January 2001 to July 2008 and the returns of an investment in the 1

Company Name	Symbol	Exchange	Industry
Active Power, Inc.	ACPW	NASDAQ	Flywheel
American Superconductor	AMSC	NASDAQ	Product or service
Arotech Corp	ARTX	NASDAQ	Fuel Cells
Beacon Power	BCON	NASDAQ	Flywheel
Ballard Power Systems	BLDP	NASDAQ	Fuel Cells
Catalytica Energy Systems	CESI	NASDAQ	Product or service
Capstone Turbine	CPST	NASDAQ	Micro Turbines
Cree Inc.	CREE	NASDAQ	Product or service
Echelon Corporation	ELON	NASDAQ	Product or service
Energy Conversion Inc.	ENER	NASDAQ	Photovoltaics
Evergreen Solar, Inc.	ESLR	NASDAQ	Photovoltaics
Fuel Cell Energy	FCEL	NASDAQ	Fuel Cells
Hydrogenics Corporation	HYGS	NASDAQ	Fuel Cells
Intermagnetics General	IMGC	NASDAQ	Product or service
Itron, Inc.	ITRI	NASDAQ	Product or service
Essex Corporation	KEYW	NASDAQ	General 1
Millennium Cell Inc.	MCEL	NASDAQ	Fuel Cells
Medis Technologies Ltd.	MDTL	NASDAQ	Fuel Cells
Methanex Corporation	MEOH	NASDAQ	Biomass
MGP Ingredients, Inc.	MGPI	NASDAQ	Biogas/Ethanol
Mechanical Technology Inc	MKTY	NASDAQ	Fuel Cells
Plug Power Inc.	PLUG	NASDAQ	Fuel Cells
Power-One	PWER	NASDAQ	Product or service
SatCon Technology Corp.	SATC	NASDAQ	Product or service
Spire Corporation	SPIR	NASDAQ	Photovoltaics
Zoltek Companies Inc.	ZOLT	NASDAQ	General 2

Table 2
The considered renewable energy companies listed in the NASDAQ. The table provides the company name, abbreviation and the industry description for each of the considered companies.

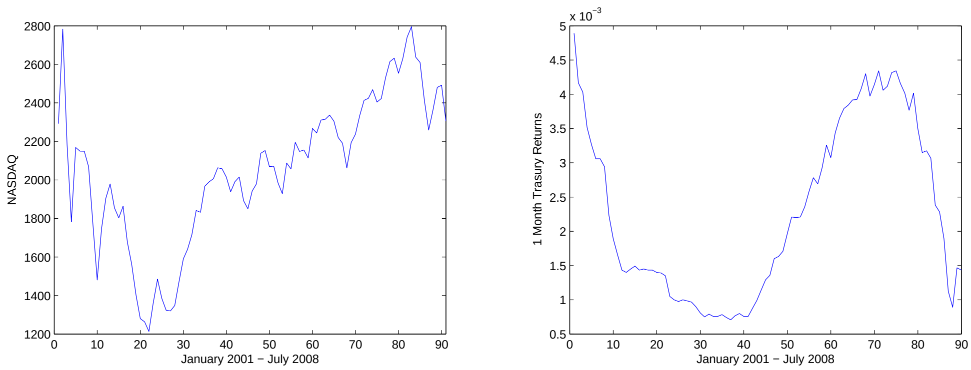

Fig. 2. NASDAQ Index for the considered time period from Jan 2, 2001 - Sep 1, 2006 (*left panel*) and 1 month US Treasury Rates (*right panel*).

month US Treasury Rates for the same period.

Table **??** shows some descriptive statistics for the monthly returns of the NASDAQ, the oil price, monthly risk-free returns and the monthly returns over all of the considered renewable energy stocks. The statistics are reported for the whole period as well as for each of the three considered subperiods. Obviously, for the NASDAQ the lowest monthly returns could be observed during the last period of steadily increasing oil prices: for the period from March 2007-July 2008 on average the index gave negative returns. For the oil price, monthly returns during the third period were about eight times higher than for the first subperiod. Naturally, returns on the risk-free rate do not show that much variation through time and remain between 0.0018 for the first subperiod and 0.0029 for the last subperiod. At a first glance, investigating the monthly average returns over all the considered renewable energy companies, we find that average monthly returns were actually the lowest for the third subperiod with 0.0049 while they were clearly higher for the first two subperiods.

From a first glance at the individual stocks we find substantial differences in the price behavior as it is indicated by figures 3 and 4. While for example the stock price for the companies Energy Conversion Inc. and Methanex seem to indicate a positive relationship with the oil price, for the flywheel stock Active Power Inc. and Ballard Power Systems specialising in fuel cells no such relationship can be observed. A more thorough investigation of the relationship will be provided in the next section.

2.2 Considered Models

Following the studies by the studies by Faff and Brailsford (1999), Sadorsky (2001) and Boyer and Filion (2004) we will apply a CAPM type and factor

Variable	Whole Period	Subperiod1	Subperiod2	Subperiod3
r_{NASDAQ}	0.0026	0.0012	0.0064	-0.0031
σ_{NASDAQ}	0.0708	0.1033	0.0373	0.0440
r_{Oil}	0.0221	0.0068	0.0206	0.0571
σ_{Oil}	0.0869	0.0929	0.0830	0.0769
r_f	0.0023	0.0018	0.0025	0.0029
σ_f	0.0013	0.0011	0.0013	0.0012
$\bar{r}_i$	0.0159	0.0157	0.0210	0.0049
σ_{r_i}	0.2408	0.2685	0.2143	0.1811

Table 3
Descriptive statistics for monthly returns of the NASDAQ index and oil price, monthly risk-free returns and the monthly returns over all of the considered renewable energy stocks. The statistics are reported for the whole period as well as for each of the three considered subperiods.

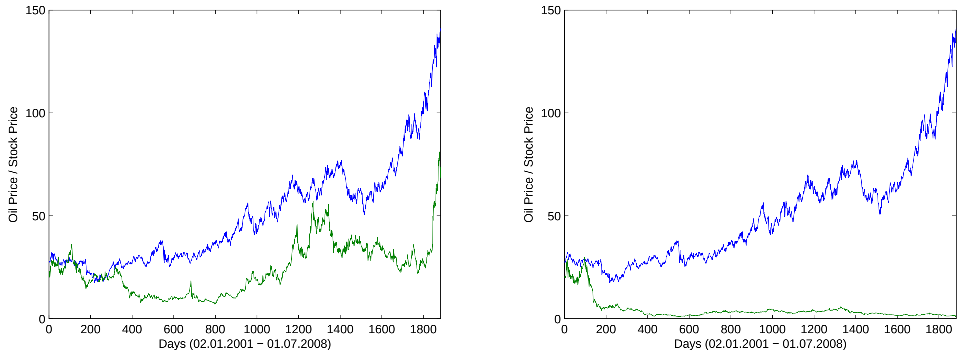

Fig. 3. Oil price and spot price for renewable energy companies Energy Conversion Inc. (*left panel*) and Active Power Inc. for Jan 2, 2001 - Sep 1, 2006 (*right panel*).

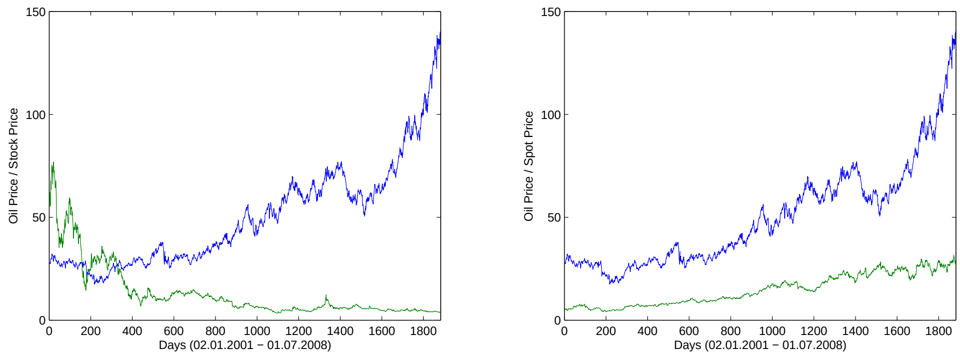

Fig. 4. Oil price and spot price for renewable energy companies Ballard Power Systems (*left panel*) and Methanex Corporation for Jan 2, 2001 - Sep 1, 2006 (*right panel*).

models to explain the observed returns of the considered companies. Hereby, the CAPM model takes the following form:

$$r_i^* = \alpha_i + \beta_i(r_m - r_f) + \epsilon_i \tag{1}$$

where $r_i^* = (r_i - r_f)$ denotes the excess return over the risk-free rate for stock i, β_i the beta-factor for stock i, α_i the average abnormal return over the expected return $\beta_i(r_m - r_f)$ for stock i and ϵ_i the error terms. Note that we consider the return of the NASDAQ index as representing the returns of the market. To measure the performance of the renewable energy stocks we also consider the Sharpe ratio for the different periods. The Sharpe ratio relates the mean excess return over the riskfree rate to the standard deviation of the excess returns:

$$S = \frac{E(r_i - r_f)}{\sqrt{var(r_i - r_f)}} \tag{2}$$

where $E(r_i - r_f)$ denotes the expected or mean excess return over the risk-free rate for stock i that is divided by the standard deviation of $(r_i - r_f)$.

We also apply a multifactor model similar to the studies by Faff and Brailsford (1999), Sadorsky (2001) and Boyer and Filion (2004) including the oil price and riskfree rate as factors determining the returns of the renewable energy companies for the different subperiods. Generally, the model takes the form

$$r_i^* = \lambda_{0,i} + \sum_{j=1}^{n} \lambda_{i,j} F_{i,j} + \epsilon_i. \tag{3}$$

Again, r_i^* denotes the excess return over the risk free rate for stock i, while the $\lambda_{i,j}$ denote the factor weights for factor j for stock i, $\lambda_{0,i}$ the abnormal return over the expected return $\sum_{j=1}^{n} \lambda_{i,j} F_{i,j}$ for stock i and ϵ_i the error term.

3 Empirical Results

To begin our empirical analysis, we investigate the calculated Sharpe ratios for the whole period and the considered subperiods. Note that for the whole period seven out of the 25 considered stocks, actually showed a negative Sharpe ratio indicating that the stocks provided negative excess returns, thus returns below the risk-free rate. For the subperiods, we obtain six (first subperiod), seven (second subperiod) and nine (third subperiod) stocks with a negative Sharpe ratio. The average Sharpe ratio over all renewable stocks is 0.0562 for the whole period, 0.0523 for the first subperiod, 0.0694 for the second subperiod and with 0.0022 clearly the lowest for the third subperiod. The comparable figures for the NASDAQ index are 0.0038 for the whole period and −0.0057, 0.1038, −0.1363 for the three subperiods. While it is obvious that on average the excess return per unit of risk is actually the lowest for the subperiod with steeply increasing oil prices, it has to be taken into account that this was also the period where the NASDAQ index on average provided negative returns. Therefore, it will be necessary to examine the returns from renewable energy companies with respect to the return of the overall index and other factors.

3.1 Results for the CAPM Models

Tables 6,, and provide the estimated regression coefficients for the CAPM type model that was applied to the data. We will first have a look at the estimated constant for the regression model that can be interpreted as the average abnormal return over the expected return $\beta_i(r_m - r_f)$ for stock i. We find that for the whole period 16 stocks provide positive abnormal returns while for the considered subperiods the numbers are 16, 11 and 14. Obviously, the number of renewable energy stocks with a positive abnormal return according to the CAPM model is not higher for the last subperiod with steeply increasing oil prices. Further note that only a small number of coefficients were significantly different from zero even at the modest 10% level in the estimated models. For the last subperiod, only AMSC and CPST provide significantly average positve abnormal returns according to the CAPM model while there are also three stocks with significant negative abnormal returns: MCEL, MGPI, MKTY.

Further findings examining the significance of the estimated beta factors are the following: while for the whole period and the first subperiod most of the estimated beta-coefficients are significant even at the 1% level, for the second and third subperiods with increasing oil prices, the number of significant beta-coefficients decreases substantially. This may also due to the substantially lower explanatory poer of the model for these periods.

Table 5 reports the coefficients of determination R^2 for the estimated CAPM model for the whole period and the three subperiods. Considering the whole period, the average R^2 is 0.1849 indicating that approximately 18% of the variation in the returns of renewable energy companies could be explained by the NASDAQ returns. However, the figures for the individual models show a large variation. While the highest $R^2 = 0.5303$ can be observed for PWER, the lowest explanatory power $R^2 = 0.0096$ is obtained for ZOLT. The average R^2 is significantly higher (0.2993) for the first subperiod and significantly lower (0.1098 and 0.1025) for the second and third subperiod with increasing oil prices. So overall, it seems that a CAPM type model provide a higher explanatory power for returns of renewable energy stocks during times of rather stable oil prices.

3.2 Multifactor Models

We will start with an investigation of the explanatory power of the multifactor models in comparison to the CAPM type model. Table 10 reports the coefficients of determination for the estimated multifactor models for each of the individual stocks. Again the results are reported for the whole period as well as for the three subperiods. The average R^2 for the factor models applied to the whole period is 0.2091 and therefore slightly higher than for the estimated CAPM models. Therefore, on average approximately 21% of the variation in the returns of renewable energy companies could be explained by NASDAQ returns, changes in the oil price and riskfree monthly returns. Considering the subperiods, we find that similar to the CAPM approach, R^2 is significantly higher (0.3525) for the first subperiod when oil prices remained at a price level around 30 Euro. However, an interesting results is that also for the third subperiod with steeply increasing oil prices $R^2 = 0.2761$ is significantly higher and on average approximately 28% of the variation in renewable energy stock returns can be explained.

Of course, in this analysis we are also interested in investigating the significance of the individual coefficients and in particular whether changes in the oil price have a significant impact on the observed returns for renewable energy stocks. Parameter estimates for the coefficients for the whole period and the three subperiods are provided in Table 11, 12, 13 and 14.

Let us first consider the number of stocks yielding positive abnormal returns with respect to the estimated factor models. While for the whole period, 15 stocks provide positive abnormal returns, for the first and second subperiod we observe 11 stocks. Surprisingly, during the period of a substantial increase in the oil price only seven out of 23 stocks yield positive abnormal returns. Hereby, none of the estimated coefficients is significantly different from zero. Similar to the CAPM type model results, most of the estimated beta factors are highly significant considering the whole period. Additionally, we find that for the estimated factor models also during the subperiod the NASDAQ index returns are estimated to be significant. On the other hand, riskfree returns obtained by the 1 month Treasury rates are mostly insignificant.

Finally, our main focus should be dedicated to the estimated influence of changes in the oil price on the returns of the considered stocks. We find that the results at least somehow support the assumption of higher investments or returns for renewable energy stocks during times of steeply increasing oil prices. For the whole period, for 13 out of 23 stocks we obtain a positive coefficient for the change in oil prices. While the number decreases to seven for the period with a relatively constant oil price, for the second and third subperiod a higher number of 16, respectively 17 coefficients are positive. Note however, that only a small number of these coefficients is actually significant. For the period of steeply increasing prices we find eight coefficients to be signifcant at the 10% level. At least all of these coefficients are positive while none of the negative coefficients is significant for these periods. The companies indicating a positive effect are the fuel cell companies BLDP, FCEL, HYGS, PLUG, as well as CPST (microturbine) and all of the considered companies specialising in photovoltaics: ENER, ESLR and SPIR. We conclude that there is some support for an increasing influence of changes in the oil price on returns from renewable energy companies during the oil price shock, in particular from companies from photovoltaic and fuel cell industries.

4 Conclusion

We investigated the influence of changes in the oil price on the returns of renewable energy companies. Hereby, we follow and extend the analysis of earlier studies by Boyer and Filion (2004), Faff and Brailsford (1999), Sadorsky (2001) and Henriques and Sadorsky (2008). We provide new contributions to the literature in two perspectives: firstly, next to the work by Henriques and Sadorsky (2008) this is only the second study concentrating in particular on stock returns of renewable energy companies. Further we also investigate individual stock returns and not just the returns of a renewable energy index. More than 20 companies from different industries like fuel cells, photovoltaics, biomass etc. listed in the NASDAQ were investigated using a CAPM type and factor model approach. The time period considered was from January 2001 to July 2008 and could be split into three subperiods: from January 2001 to December 2003 when the oil price remained relatively constant around a level of 30 USD, the period from January 2004 to February 2007 when the oil prices showed an overall tendency to increase up to 60 USD and the period from March 2007 to July 2008 when an extreme increase in the prices up to 140 USD could be observed. Investigating the explanatory power of the CAPM type model, we find that for the second and third superiod when the oil price was rising, the models on average only explain around 10% of the variation in returns from renewable energy companies. On the other hand, the inclusion of the variables oil price and the riskfree improved the coefficient of determination in particular these periods. For neither of the two approaches significant abnormal returns for the companies could be observed. Actually the number of companies with average positive abnormal returns was even the smallest during the subperiod with a steeply increasing oil price. On the other hand, for the applied factor model, the number of positive coefficients for the changes in the oil price increases from seven to 16, respectively 17 for the subperiods with increasing oil prices. We also find a clearly higher number of the coefficients to be significant in particular for companies in the fuel cell and photovoltaic industry. Further, our results emphasize the importance of a distinction between different phases of oil price behavior when investigating the influence on stock returns of renewable energy companies.

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Variable	Whole Period	Subperiod1	Subperiod2	Subperiod3
ACPW	-0.0826	-0.0753	-0.0082	-0.2791
AMSC	0.1083	0.0473	0.0210	0.5654
ARTX	-0.0503	0.0701	-0.1779	-0.1173
BCON	0.0794	0.0106	0.1051	0.2325
BLDP	-0.0760	-0.0798	-0.0602	-0.1274
CPST	0.0537	-0.0810	0.0553	0.6301
CREE	0.0623	0.0481	0.0331	0.2150
ELON	0.0671	0.0759	-0.0733	0.1937
ENER	0.1431	-0.0818	0.2746	0.2294
ESLR	0.1204	0.0229	0.2806	0.1073
FCEL	-0.0178	-0.0083	-0.0793	0.0745
HYGS	0.0805	0.1584	-0.2701	0.2294
ITRI	0.2835	0.3052	0.2747	0.3520
MCEL	-0.1795	-0.0534	-0.0338	-0.8538
MDTL	0.0306	0.0816	0.1288	-0.2868
MEOH	0.2013	0.1791	0.3083	0.0334
MGPI	0.0873	0.1229	0.2506	-0.4680
MKTY	0.0964	0.1754	0.1497	-0.6503
PLUG	-0.0409	-0.0080	-0.0494	-0.1810
PWER	-0.0360	0.0135	0.0343	-0.3630
SATC	0.0414	0.0351	-0.0540	0.3027
SPIR	0.1464	0.1124	0.1706	0.1831
ZOLT	0.1739	0.1329	0.3146	0.0294

Table 4
Estimated Sharpe ratios for whole period as well as for first, second and third subperiod. The average Sharpe ratio is 0.0562 for the whole period, 0.0523 for the first subperiod, 0.0694 for the second subperiod and with 0.0022 clearly the lowest for the third subperiod.

5 Appendix

Variable	Whole Period	Subperiod1	Subperiod2	Subperiod3
ACPW	0.2689	0.3633	0.1500	0.0279
AMSC	0.2260	0.2544	0.2751	0.1021
ARTX	0.0886	0.1396	0.0019	0.1974
BCON	0.0955	0.1778	0.0134	0.0459
BLDP	0.3653	0.6648	0.0244	0.0017
CPST	0.1518	0.3426	0.0225	0.0462
CREE	0.3741	0.4478	0.3593	0.0853
ELON	0.3655	0.5428	0.3096	0.1772
ENER	0.0980	0.3962	0.0006	0.0082
ESLR	0.1281	0.1672	0.0543	0.0653
FCEL	0.2040	0.3046	0.0085	0.3124
HYGS	0.2824	0.6446	0.1093	0.0228
ITRI	0.0688	0.0586	0.1309	0.1185
MCEL	0.1559	0.4120	0.0066	0.0054
MDTL	0.1438	0.1862	0.0763	0.1023
MEOH	0.0245	0.0034	0.2774	0.0113
MGPI	0.0444	0.0883	0.0406	0.0693
MKTY	0.0392	0.3114	0.0094	0.0038
PLUG	0.3166	0.3886	0.0961	0.2813
PWER	0.5303	0.6026	0.3639	0.3210
SATC	0.0768	0.0906	0.0951	0.0004
SPIR	0.1952	0.2961	0.0760	0.1073
ZOLT	0.0096	0.0016	0.0250	0.2435

Table 5
Coefficients of determination R^2 for CAPM model for whole period and the three subperiods. The average R^2 is 0.1849 for the whole period, while it significantly higher (0.2993) for the first subperiod and significantly lower (0.1098 and 0.1025) for the second and third subperiod with increasing oil prices.

Variable	α_i	se_{α_i}	β_i	se_{β_i}
ACPW	-0.0162	(0.0173)	1.3988***	(0.2459)
AMSC	0.0218	(0.0191)	1.3748***	(0.2713)
ARTX	-0.0129	(0.0254)	1.0555***	(0.3610)
BCON	0.0264	(0.0341)	1.4740***	(0.4837)
BLDP	-0.0142	(0.0153)	1.5468***	(0.2174)
CPST	0.0159	(0.0297)	1.6725***	(0.4214)
CREE	0.0112	(0.0157)	1.6190***	(0.2232)
ELON	0.0129	(0.0168)	1.6936***	(0.2378)
ENER	0.0268	(0.0190)	0.8334***	(0.2695)
ESLR	0.0280	(0.0233)	1.1882***	(0.3305)
FCEL	-0.0035	(0.0169)	1.1386***	(0.2397)
HYGS	0.0233	(0.0266)	2.2259***	(0.3782)
ITRI	0.0477***	(0.0173)	0.6252**	(0.2453)
MCEL	-0.0421*	(0.0226)	1.2962***	(0.3215)
MDTL	0.0064	(0.0214)	1.1702***	(0.3044)
MEOH	0.0204*	(0.0106)	0.2247	(0.1511)
MGPI	0.0147	(0.0177)	0.5067**	(0.2507)
MKTY	0.0681	(0.0740)	1.9894*	(1.0500)
PLUG	-0.0078	(0.0158)	1.4343***	(0.2247)
PWER	-0.0091	(0.0170)	2.3991***	(0.2407)
SATC	0.0120	(0.0304)	1.1687***	(0.4320)
SPIR	0.0299	(0.0196)	1.2864***	(0.2785)
ZOLT	0.0452	(0.0275)	0.3599	(0.3897)

Table 6
Estimated coefficients α_i and β_i and standard errors of the coefficients for the whole estimation period. Hereby, *** denotes significance of the coefficient at the 1% level, ** at the 5% level and * at the 10% level.

Variable	α_i	se_{α_i}	β_i	se_{β_i}
ACPW	-0.0178	(0.0339)	1.4443***	(0.3329)
AMSC	0.0139	(0.0410)	1.3493***	(0.4022)
ARTX	0.0219	(0.0482)	1.0950**	(0.4733)
BCON	0.0050	(0.0599)	1.5687**	(0.5872)
BLDP	-0.0171	(0.0226)	1.7934***	(0.2217)
CPST	-0.0250	(0.0447)	1.8190***	(0.4386)
CREE	0.0127	(0.0312)	1.5833***	(0.3060)
ELON	0.0185	(0.0268)	1.6438***	(0.2626)
ENER	-0.0123	(0.0210)	0.9593***	(0.2062)
ESLR	0.0076	(0.0473)	1.1951**	(0.4643)
FCEL	-0.0012	(0.0317)	1.1821***	(0.3109)
HYGS	0.0573	(0.0360)	2.7288***	(0.3527)
ITRI	0.0707*	(0.0384)	0.5396	(0.3764)
MCEL	-0.0116	(0.0306)	1.4426***	(0.3000)
MDTL	0.0223	(0.0411)	1.1076***	(0.4031)
MEOH	0.0200	(0.0191)	0.0628	(0.1876)
MGPI	0.0154	(0.0202)	0.3545*	(0.1983)
MKTY	0.0648	(0.0517)	1.9598***	(0.5073)
PLUG	-0.0011	(0.0332)	1.4895***	(0.3253)
PWER	0.0057	(0.0345)	2.3919***	(0.3381)
SATC	0.0158	(0.0701)	1.2470*	(0.6878)
SPIR	0.0279	(0.0348)	1.2719***	(0.3414)
ZOLT	0.0456	(0.0587)	0.1331	(0.5762)

Table 7
Estimated coefficients α_i and β_i and standard errors of the coefficients for the first subperiod. Hereby, *** denotes significance of the coefficient at the 1% level, ** at the 5% level and * at the 10% level.

Variable	α_i	se_{α_i}	β_i	se_{β_i}
ACPW	-0.0070	(0.0220)	1.5043**	(0.596)
AMSC	-0.0046	(0.0193)	1.9387***	(0.5245)
ARTX	-0.0398	(0.0360)	0.2526	(0.9775)
BCON	0.0315	(0.0555)	1.0552	(1.5068)
BLDP	-0.0124	(0.0266)	0.6844	(0.7218)
CPST	0.0133	(0.0547)	1.3538	(1.4856)
CREE	-0.0044	(0.0200)	2.4425***	(0.5436)
ELON	-0.0146	(0.0153)	1.6735***	(0.4165)
ENER	0.0498	(0.0303)	0.1252	(0.8218)
ESLR	0.0477	(0.0299)	1.1671	(0.8116)
FCEL	-0.0126	(0.0233)	0.3508	(0.6333)
HYGS	-0.0415	(0.0213)	1.2127**	(0.5770)
ITRI	0.0293	(0.0190)	1.2039**	(0.5169)
MCEL	-0.0095	(0.0372)	0.4943	(1.0095)
MDTL	0.0172	(0.0273)	1.2798*	(0.7421)
MEOH	0.0234*	(0.0130)	1.3101***	(0.3524)
MGPI	0.0473	(0.0333)	1.1161	(0.9042)
MKTY	0.1439	(0.1696)	2.6904***	(4.6030)
PLUG	-0.0105	(0.0202)	1.0722*	(0.5479)
PWER	-0.0042	(0.0196)	2.4156***	(0.5323)
SATC	-0.0149	(0.0273)	1.4420*	(0.7415)
SPIR	0.0262	(0.0293)	1.3685*	(0.7953)
ZOLT	0.0596*	(0.0326)	0.8512	(0.8857)

Table 8
Estimated coefficients α_i and β_i and standard errors of the coefficients for the second subperiod. Hereby, *** denotes significance of the coefficient at the 1% level, ** at the 5% level and * at the 10% level.

Variable	α_i	se_{α_i}	β_i	se_{β_i}
ACPW	-0.0390	(0.0380)	0.5801	(0.8839)
AMSC	0.0906***	(0.0356)	1.0832	(0.8296)
ARTX	-0.0116	(0.0463)	2.0704**	(1.0779)
BCON	0.0611	(0.0577)	1.1404	(1.3420)
BLDP	-0.0131	(0.0271)	0.1012	(0.6309)
CPST	0.1032***	(0.0387)	0.7676	(0.9001)
CREE	0.0313	(0.0297)	0.8177	(0.6914)
ELON	0.0684	(0.0625)	2.6156*	(1.4550)
ENER	0.0601	(0.0626)	0.5143	(1.4566)
ESLR	0.0251	(0.0432)	1.0284	(1.0043)
FCEL	0.0244	(0.0340)	2.0642***	(0.7908)
HYGS	0.0856	(0.1025)	-1.4110	(2.3855)
ITRI	0.0372	(0.0222)	0.7327	(0.5159)
MCEL	-0.1763***	(0.0527)	0.3510	(1.2268)
MDTL	-0.0498	(0.0491)	1.4936	(1.1427)
MEOH	0.0050	(0.0261)	0.2519	(0.6078)
MGPI	-0.0625*	(0.0353)	0.8677	(0.8213)
MKTY	-0.1111**	(0.0437)	0.2437	(1.0173)
PLUG	-0.0125	(0.0247)	1.3923**	(0.5746)
PWER	-0.0510	(0.0372)	2.3071**	(0.8665)
SATC	0.0560	(0.0463)	0.0817	(1.0786)
SPIR	0.0419	(0.0440)	1.3744	(1.0234)
ZOLT	0.0174	(0.0396)	2.0232**	(0.9208)

Table 9
Estimated coefficients α_i and β_i and standard errors of the coefficients for the third subperiod of steeply increasing oil prices. Hereby, *** denotes significance of the coefficient at the 1% level, ** at the 5% level and * at the 10% level.

Variable	Whole Period	Subperiod1	Subperiod2	Subperiod 3
ACPW	0.2748	0.3742	0.1674	0.0480
AMSC	0.2311	0.2831	0.2851	0.4158
ARTX	0.0944	0.1507	0.0127	0.2720
BCON	0.1061	0.2449	0.0668	0.1021
BLDP	0.3969	0.6764	0.2482	0.2525
CPST	0.2027	0.3494	0.1815	0.5131
CREE	0.3824	0.4552	0.4537	0.2689
ELON	0.4115	0.6417	0.3137	0.2767
ENER	0.1333	0.4591	0.0440	0.3988
ESLR	0.1670	0.2032	0.1281	0.1599
FCEL	0.2547	0.3180	0.2284	0.3346
HYGS	0.3154	0.7043	0.3405	0.2437
ITRI	0.1348	0.4033	0.1805	0.4361
MCEL	0.1615	0.4273	0.0646	0.4675
MDTL	0.1441	0.1964	0.1305	0.2942
MEOH	0.0327	0.0303	0.2848	0.0993
MGPI	0.0587	0.1905	0.0626	0.1052
MKTY	0.0729	0.4052	0.0955	0.2238
PLUG	0.3483	0.4407	0.2445	0.3631
PWER	0.5429	0.6223	0.3643	0.3401
SATC	0.0812	0.1137	0.1849	0.2120
SPIR	0.2324	0.3867	0.0917	0.2208
ZOLT	0.0303	0.0317	0.0339	0.3014

Table 10
Coefficients of determination R^2 for the multifactor models are reported for the whole period, the first, second and third subperiod. The average R^2 is 0.2091 for the whole period. Similar to the CAPM approach, R^2 is significantly higher (0.3525) for the first subperiod. However, also for the third subperiod R^2 is 0.2761 and thus, comparably high. The lowest average R^2 of 0.1830 can be observed for the second subperiod.

Variable	β_0	β_{Nasdaq}	β_{Oil}	$\beta_{riskfree}$
ACPW	0.0109	1.3936***	-0.0577	-0.1127
AMSC	0.0313	1.3645***	0.1420	-0.0552
ARTX	0.0227	1.0465***	-0.0342	-0.1524
BCON	0.0674	1.4487***	0.2466	-0.2028
BLDP	-0.0487	1.5393***	0.3458*	0.1172
CPST	0.0067	1.6344***	0.7837**	-0.0355
CREE	0.0335	1.6211***	-0.1696	-0.0808
ELON	-0.0515	1.7229***	-0.1863	0.2992**
ENER	0.0292	0.8121***	0.3951*	-0.0489
ESLR	0.0151	1.1642***	0.5352**	0.0048
FCEL	-0.0050	1.1153***	0.4545**	-0.0374
HYGS	0.0255	2.1937***	0.6029*	-0.0681
ITRI	-0.0147	0.6557***	-0.2202	0.2942**
MCEL	-0.0591	1.2914***	0.1911	0.0557
MDTL	0.0133	1.1689***	-0.0154	-0.0289
MEOH	0.0210	0.2192	0.1023	-0.0125
MGPI	0.0435	0.5079**	-0.1906	-0.1073
MKTY	-0.0796	2.0843***	-0.9570	0.7383
PLUG	-0.0296	1.4217***	0.3687**	0.0597
PWER	0.0288	2.4001***	-0.2389	-0.1425
SATC	0.0350	1.1542***	0.1426	-0.1141
SPIR	-0.0236	1.2826***	0.3853*	0.1966
ZOLT	0.0592	0.3782	-0.4332	-0.0196

Table 11
Estimated coefficients α_i and β_i and standard errors of the coefficients for the whole period. Hereby, *** denotes significance of the coefficient at the 1% level, ** at the 5% level and * at the 10% level.

Variable	β_0	β_{Nasdaq}	β_{Oil}	$\beta_{riskfree}$
ACPW	0.0222	1.4263***	-0.1031	-0.2226
AMSC	0.0810	1.3313***	-0.2730	-0.3688
ARTX	0.0730	1.0611***	-0.0425	-0.2877
BCON	0.1455	1.5349***	-0.6049	-0.7714
BLDP	-0.0327	1.8335***	-0.2326*	0.0971
CPST	-0.0559	1.8637***	-0.1740**	0.1815
CREE	0.0120	1.6113***	-0.2263	0.0129
ELON	-0.0679	1.7666***	-0.4681	0.5069
ENER	-0.0717	1.0181***	-0.1113*	0.3398
ESLR	-0.0274	1.1494***	0.5969**	0.1752
FCEL	0.0297	1.1388***	0.1624**	-0.1809
HYGS	-0.0757	2.8483***	-0.1478*	0.7581
ITRI	-0.1334	0.7391***	-0.3599	1.1678**
MCEL	-0.0134	1.4061***	0.3119	-0.0016
MDTL	-0.0026	1.1534***	-0.2203	0.1495
MEOH	0.0179	0.0403	0.1992	0.0046
MGPI	0.0256	0.3987**	-0.4280	-0.0410
MKTY	-0.0381	1.9108**	1.0500	0.5419
PLUG	-0.0884	1.5297***	0.2170**	0.4851
PWER	0.0435	2.4161***	-0.4366	-0.1968
SATC	0.0767	1.2750***	-0.6136	-0.3210
SPIR	-0.0663	1.2799***	0.5266*	0.5126
ZOLT	0.0702	0.1918	-0.6379	-0.1142

Table 12
Estimated coefficients β_0; β_{Nasdaq}; β_{Oil} and $\beta_{riskfree}$ for the first subperiod. Hereby, *** denotes significance of the coefficient at the 1% level, ** at the 5% level and * at the 10% level.

Variable	β_0	β_{Nasdaq}	β_{Oil}	$\beta_{riskfree}$
ACPW	0.0304	1.5378***	-0.0038	-0.1499
AMSC	-0.0027	2.0081***	0.1561	-0.0217
ARTX	-0.0834	0.3018***	0.2084	0.1568
BCON	-0.0170	1.4368***	0.9861	0.1066
BLDP	-0.1206	0.9814***	0.9204*	0.3523
CPST	-0.0149	2.0308***	1.6240**	-0.0318
CREE	0.0921	2.4793***	-0.1247	-0.3765
ELON	-0.0288	1.6615***	0.0031	0.0567*
ENER	0.0893	0.2926***	0.3010*	-0.1854
ESLR	0.0993	1.3898***	0.4021**	-0.2431
FCEL	-0.0519	0.6771***	0.8385**	0.0829
HYGS	-0.0355	1.5454***	0.7550*	-0.0914
ITRI	0.0549	1.0773***	-0.3479	-0.0719**
MCEL	-0.0474	0.7570***	0.6887	0.0907
MDTL	0.0804	1.4124***	0.1691	-0.2687
MEOH	0.0356	1.3375	0.0369	-0.0520
MGPI	0.0469	1.2713**	0.3590	-0.0307
MKTY	-0.0346	1.2209**	-3.0049	0.9848
PLUG	0.0036	1.3210***	0.5438**	-0.1050
PWER	-0.0024	2.4016***	-0.0363	-0.0041
SATC	-0.0560	1.6894***	0.6603	0.1061
SPIR	0.0420	1.4789***	0.2206*	-0.0833
ZOLT	0.0881	0.7828	-0.2196	-0.0947

Table 13
Estimated coefficients β_0; β_{Nasdaq}; β_{Oil} and $\beta_{riskfree}$ for the second subperiod. Hereby, *** denotes significance of the coefficient at the 1% level, ** at the 5% level and * at the 10% level.

Variable	β_0	β_{Nasdaq}	β_{Oil}	$\beta_{riskfree}$
ACPW	-0.0936	0.5314***	0.0169	0.1849
AMSC	-0.0328	0.9394***	1.1014	0.2071
ARTX	0.1340	2.2159***	-0.5352	-0.3962
BCON	0.0387	1.0986***	0.6951	-0.0609
BLDP	-0.0651	0.0328***	0.7083*	0.0388
CPST	0.2504	0.8733***	0.7714**	-0.6614
CREE	-0.0521	0.7543***	-0.3253	0.3524
ELON	-0.1292	2.4449***	-0.1266	0.7072
ENER	0.2053	0.5983***	1.4057*	-0.7808
ESLR	-0.0818	0.9124***	0.6839**	0.2330
FCEL	-0.0201	2.0151***	0.3098**	0.0921
HYGS	0.2253	-1.3471***	1.8881*	-0.8576
ITRI	-0.0388	0.6435***	0.6963	0.1240**
MCEL	-0.5027	0.0692***	-0.2105	1.1688
MDTL	-0.2967	1.2555***	0.6296	0.7271
MEOH	-0.0310	0.2072	0.4087	0.0430
MGPI	0.0095	0.9395**	-0.2586	-0.1970
MKTY	-0.2787	0.1041**	-0.2682	0.6318
PLUG	-0.0490	1.3463***	0.4364**	0.0393
PWER	-0.0078	2.3412***	0.1306	-0.1752
SATC	0.0444	0.0393*	1.0197	-0.1627
SPIR	-0.1279	1.2097***	0.4621*	0.4942
ZOLT	-0.0727	1.9480	-0.1378	0.3382

Table 14
Estimated coefficients β_0; β_{Nasdaq}; β_{Oil} and $\beta_{riskfree}$ for the third subperiod. Hereby, *** denotes significance of the coefficient at the 1% level, ** at the 5% level and * at the 10% level.